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Describes the results of an investigation of methods of presenting programed material which might speed up the learning process without adversely affecting final performance. Participants in the experiment were 189 freshmen engineering students.

The test material included 6 introductory items, 93 items covering 7 concepts of elementary probability, and 14 criterion test items (2 for each of the concepts). Data were recorded on learning time, error score during learning, criterion test time and criterion test score.

Findings revealed that the program was effective in significantly changing the performance level of the students and that careful sequencing of items had a significant effect on student performance (at least for programs of some length and complexity). While there was a significant difference in learning time (but not in test scores) favoring the forward over the backward branching procedures, there was no significant difference in either learning time or test scores between the forward branching and the linear methods. In summary, the simple branching procedures tested did not, by and large, seem to be more effective than a linear procedure.

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A Comparison of Branching Methods for Programmed Learning

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IN EARLIER STUDIES [1*] with linear programs, where each student had to go through all the items in a predetermined sequence, we failed to find any significant differences in the terminal performance of students who had worked with multiple choice machines, composed response machines, programmed texts requiring overt responses, and programmed texts requiring no responses. However, significant differences had been obtained in the amount of time required to complete the learning session. We therefore decided to investigate those methods of presenting programmed material which might speed up the learning process without adversely affecting terminal performance.

Many varieties of branching programs have been suggested to accomplish this purpose (backward branching to missed items, backward branching to review an entire sequence of items, backward branching to alternate form items, lateral branching to supplemental or prerequisite material, branching down to more detailed items for slow students, branching up to faster programs for bright students, forward branching, etc.), but very few experiments[2] have compared the relative merits of the various branching methods. Early in the analysis of the problem, we concluded that all types of branching and linear programs are reducible to one common prototype form (selective forward branching), and that the distinction between the various name-types is more arbitrary than is commonly suspected [3]. Furthermore, by casting all of the "different" types of branching procedures we wished to investigate into the prototype form, we could physically present all branching formats in one simple inexpensive device.

Equipment

A cardboard box[4] capable of holding two hundred 4- by 6-inch cards, each of which is one complete item in a program, was devised to solve the problem of presenting different kinds of branching programs simultaneously to a large number of students in an experimental situation. Since the experimental design required a record of each student's responses to individual items in the program, a device which could effectively control student behavior, thereby permitting measurement of time during learning, was essential. Cost restrictions precluded the use of expensive electro-mechanical devices. A scrambled textbook was ruled out because of the difficulty of controlling browsing or peeking ahead for correct answers.

Made of inexpensive railroad board, the box is easily assembled by drawing a pattern on the board, cutting it out with a razor, then folding and fastening it with staples and rubber cement (Figure 1). A condensed list of instructions on the use of the device is attached to the front of the box.

Numbered cards, each consisting of one item in the program, are arranged like a card file in the rear section of the box. A series of colored file break cards with numbered tabs divide the item cards, which also have numbered tabs, into groups for easy access to an individual card. Each branching sequence is scrambled in order to prevent browsing and to conceal the program format.

Item cards, which are either of the multiple-choice or composed-response type, are mimeographed. Below each of the answer choices on the multiple-choice type, or below the space for writing in answers in the composed-response type, is the correct answer as well as directions to the next card in the sequence. This information appears within the bottom inch of the card, an area which is covered with cellophane tape. A china marking pencil is used over the tape to black out the correct answers and directions. To indicate his answer, the student removes the black patch below his choice, thus giving a permanent record of his response. After the student has noted the correct answer and the number of the next card,

* Footnotes will be found at the end of the article.

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he inserts the card into the front section of the box. The mask tab must be raised to allow insertion of a card through the slot in the upper left-hand side of the box (Figure 2). When the tab is released, the mask conceals the entire card except for the directions to the next card which are visible through an opening at the top (front) of the box and a cutout portion of the mask. From the discarded items in this front section, a record of the sequence which the student has followed is available to the experimenter.

Instructions which appear on the first five cards of the sequence establish a behavioral pattern of working one card at a time, slipping it into the box, then selecting the next card in the specified order. Thus, not more than one card is out of the box at any time. Most students who participated in the experiment were able to follow the procedure as outlined on the cards without additional verbal instructions.

Subjects

The subjects of this experiment were the 189 students enrolled in the freshman engineering laboratory course at UCLA during the fall, 1961, semester. The students were classified into aptitude thirds according to their scores on the Mathematical Reasoning Score on the UCLA Lower Division Engineering Examination (formerly used as a college admission examination). Within each aptitude third, students were randomly assigned to seven groups. The first group (linear) worked through each item in the program. The second group (forward) branched forward if their responses to key items indicated a knowledge of the particular concept being dealt with. The third group (backward) saw each item and at the end of a group of items covering a particular concept, if their responses indicated they had not mastered that concept, branched back to the same sequence of items a second time. The fourth group (backward alternate) followed the same procedure as the third group but instead of branching back to a repetition of the same items, they were branched to alternate items covering the same concept. The fifth group (pretest forward) differed from the forward-branching group in that they took the criterion test before they had a chance to see the program and then repeated the test at the end of the program. The sixth group (random) worked through the same items as the linear group, but the ordering of items was random rather than sequential. The seventh group (text) was given the forward-branching program in the form of a text book instead of the card file.

In all the branching programs, two key branching items were used in preference to a single one to test the student's mastery of a concept, in order to reduce the possibility of the student's guessing the correct answer and thereby skipping over a sequence of items which he did not really know (Figure 3).

Material

The program consisted of six introductory and instruction items, 93 items covering seven concepts of elementary probability (relationship between information, degree of certainty, and probability measure; sum of probabilities, range of probabilities; additive law for mutually exclusive events; multiplicative law for independent events; multiplicative law for dependent events; union of events; union of complementary events), and 14 criterion test items (two for each of the concepts). The programmed material was administered first to a few individual students, revised, tried in a pilot study with 55 students in a similar freshman laboratory group during the spring of 1961,[5] revised again, tried on six individual students, and revised for the last time prior to the September, 1961, experiment.

Procedure

Approximately eighty students at a time met together in a large room during their regular scheduled freshman engineering laboratory class hours in the second week of the fall, 1961, semester (see Figure 4). The subject content was part of the required curriculum and students were informed that the final examination at the end of the semester would include questions on elementary probability.

Forward, backward, backward alternate, linear, random, and pretest forward programs were used by different students in the classroom at the same time. However, since the card handling procedure with the special boxes was the same for all methods, the students were not aware that different sequences of items were being presented to other students. The group of students who used the forward branching programmed texts met together in a separate room.

Data was recorded on the learning time, error score during learning, criterion test time, and criterion test score.

Results

The data were in all cases first tested for interaction effects between aptitude and time or score by analyses of variance. Since no interactions were observed, the aptitude scores were used as a covariate with the dependent variables, and analyses of covariance results are reported below. Normality of distribution and homogeneity of variance requirements were satisfied in all cases.

In evaluating the results of the experiment, the

first question posed was whether the programmed material contributed significantly to final student performance. Comparisons were made between (1) pre-learning test scores versus post-learning test scores for the pretest forward group, and (2) pre-learning test scores of the pretest forward group versus post-learning test scores for the combined linear, backward, backward alternate and forward groups. Tables I and II show a highly significant difference in test scores (pre-learning mean score: 29.3%; post-learning mean scores: 63.8% and 65.7%) and in test time.

Overall analysis of covariance on post-learning test scores (significant at the 0.01 level), is shown in Table III, and on learning time (significant at the 0.0005 level), is shown in Table IV.

There was no significant difference in the post-learning test times between the groups (linear, forward, backward, backward alternate, random), who used the same equipment, i.e., the branching box.

Of considerable interest was the effect of careful sequencing of program items on learning. A previous study [6] had indicated that for short programs careful sequencing may not be important. A comparison of the random and linear groups in the experiment, shown in Table V, indicates that the random sequence group performed significantly worse on learning time, errors made during learning, and on post-learning test score.

Comparison of other pairs of methods indicated no significant differences between the linear and forward branching methods (Table VI), no significant differences between the backward and backward alternate methods (Table VII), a significant difference only in learning time between linear versus combined backward and backward alternate methods (Table VIII), and similarly a significant difference only in learning time between the forward versus combined backward and backward alternate methods (Table IX). A comparison of forward versus the pretest forward groups shows the pretest group taking significantly less time for learning and for the posttest (Table X).

A comparison of the groups which had the forward-branching program in the box versus the group which had the forward-branching program in the form of a text indicates a significant difference only in the learning time (Table XI).

A comparison of the amount of branching for each of the seven concepts is shown in Table XII.

Furthermore, in the backward branching group 17% of the students did not miss any of the decision items at the end of each concept and therefore did not have to branch back into a review of the items in that concept. The worst student had to review 57% of the items in the program, and, on the average, 34% of the items were reviewed, i.e., this group saw 1.34 times as many cards as the linear group. Similar results prevailed for the backward alternate group. In the forward group only 7% of the students failed to answer correctly on at least one of the pairs of decision items at the beginning of each concept. The brightest student saw only 43% of the items, and, on the average, this group saw 0.73 times as many cards as the linear group. The pretest forward group, on the average, saw only half as many cards as the linear group.

Conclusions

The program was effective in significantly changing the performance level of the students. Furthermore, careful sequencing of items has a significant effect on student performance, at least for programs of some length and complexity. While there was a significant difference in learning time (but not in test scores), favoring the forward over the backward branching procedures, there was no significant difference in either learning time or test scores between the forward and the linear methods. Therefore, the simple branching procedures tested here do not, by and large, seem to be more effective than a linear procedure. This, however, should not discourage investigation into more complex branching procedures, particularly those which allow modifications to the branching rules or strategies during the course of student learning.

FOOTNOTES

1. Roe, A., Massey, Mildred, Weltman, G., and Leeds, D. Automated Teaching Methods Using Linear Programs, Los Angeles: University of California, Department of Engineering, Report No. 60-105, December, 1960.
2. Coulson, J.E., and Silberman, H.F. Results of Initial Experiment in Automated Teaching, Santa Monica, California: System Development Corporation, SP-73, July, 1959.
3. Roe, A. Branching Programs in Automated Instruction: A Simplified Format, Los Angeles: University of California, Department of Engineering, Report No. 61-72, August, 1961.
4. Devised from suggestions by the author, S. Pressey, J. Rigney, Y. Filby, R. Powell, F. Saunders, K. Vlachouli, and R. Nazro.
5. With the assistance of Y. Filby and R. Nazro.
6. Roe, V.V., Case, H.W., and Roe, A. Scrambled vs. Ordered Sequence in Auto-Instructional Programs, Los Angeles: University of California, Department of Engineering, Report No. 61-48, May, 1961.

TABLE I

PRETEST FORWARD GROUP: PRE-LEARNING VS. POST-LEARNING RESULTS

	N	Adj. Mean	S.D.	V_1	V_2	F	Significance
Pre-learning test score	20	29.3	21.3	1	37	27.70	@ >.0005
Post-learning test score		63.8	21.4				
Pre-learning test time	20	39.60	9.2	1	37	52.74	@ >.0005
Post-learning test time		21.65	6.5				

TABLE II

PRETEST FORWARD GROUP: PRE-LEARNING SCORES VS. COMBINED LINEAR, BACKWARD, BACKWARD ALTERNATE, AND FORWARD POST-LEARNING SCORES

	N	Adj. Mean	S.D.	V_1	V_2	F	Significance
PF pre-learning test score	20	29.3	21.3	1	125	66.82	@ >.0005
Combined post-learning test score	108	65.7	17.0				

TABLE III

OVERALL ANALYSES OF COVARIANCE: POST-LEARNING TEST SCORES (PER CENT)

	N	Adj. Mean	S.D.	V_1	V_2	F	Significance
Linear	31	69.7	13.2				
Random	32	59.4	18.7				
Forward	26	62.4	17.9				
Pretest forward	20	63.8	21.4	6	178	2.80	@ .01
Backward	27	67.0	17.4				
Backward alternate	24	62.6	19.5				
Programmed text	26	53.2	22.5				

TABLE IV

OVERALL ANALYSES OF COVARIANCE: LEARNING TIME (MINUTES)

	N	Adj. Mean	S.D.	V_1	V_2	F	Significance
Linear	31	118.1	16.1				
Random	32	131.2	20.6				
Forward	27	110.2	23.4				
Pretest forward	20	91.9	17.9	6	181	29.7	@ >.0005
Backward	27	135.1	22.9				
Backward alternate	26	135.7	22.4				
Programmed text	26	80.2	19.3				

TABLE V

RANDOM SEQUENCE VS. LINEAR SEQUENCE

	N	Adj. Mean	S.D.	V_1	V_2	F	Significance
Learning Time							
Linear	31	118.1	16.6	1	60	7.6	@ .003
Random	32	131.2	20.6				
Error Score During Learning							
Linear	31	9.97	5.3	1	60	58.7	@ >.0005
Random	32	21.44	6.8				
Test Time							
Linear	31	27.2	4.6	1	60	.01	N.S.
Random	32	26.7	6.3				
Test Scores							
Linear	31	69.7	13.2	1	60	6.9	@ .01
Random	32	59.4	18.7				

TABLE VI

LINEAR VS. FORWARD

	N	Adj. Mean	S.D.	V_1	V_2	F	Significance
Test Score							
Linear	31	69.7	13.2	1	54	3.3	N.S.
Forward	26	62.4	17.9				
Learning Time							
Linear	31	118.1	16.6	1	55	2.2	N.S.
Forward	27	110.2	23.3				
Test Time							
Linear	31	27.2	4.6	1	55	.01	N.S.
Forward	27	27.3	5.7				

TABLE VII

BACKWARD VS. BACKWARD ALTERNATE

	N	Adj. Mean	S.D.	V_1	V_2	F	Significance
Test Score							
Backward	27	67.0	17.4	1	48	.99	N.S.
Backward Alternate	24	62.6	19.5				
Learning Time							
Backward	27	135.1	22.9	1	50	.02	N.S.
Backward Alternate	26	135.7	22.4				
Test Time							
Backward	26	25.5	6.9	1	45	.01	N.S.
Backward Alternate	22	25.0	5.2				

TABLE VIII

LINEAR VS. COMBINED BACKWARD AND BACKWARD ALTERNATE

	N	Adj. Mean	S.D.	V_1	V_2	F	Significance
Test Score							
Linear	31	69.7	13.2	1	79	1.29	N.S.
Combined Backward	51	64.9	18.4				
Learning Time							
Linear	31	118.1	16.6	1	81	13.2	@ >.0005
Combined Backward	53	135.4	22.4				
Test Time							
Linear	31	27.2	4.6	1	76	4.4	N.S.
Combined Backward	48	25.3	6.1				

TABLE IX

FORWARD VS. COMBINED BACKWARD AND BACKWARD ALTERNATE

	N	Adj. Mean	S.D.	V_1	V_2	F	Significance
Test Score							
Forward	26	62.4	17.9	1	74	0.61	N.S.
Combined Backward	51	64.9	18.4				
Learning Time							
Forward	27	110.2	23.2	1	77	20.9	@ >.0005
Combined Backward	53	135.4	22.4				
Test Time							
Forward	27	27.3	5.7	1	72	2.2	N.S.
Combined Backward	48	25.3	6.1				

TABLE X

FORWARD VS. PRETEST FORWARD

	N	Adj. Mean	S.D.	V_1	V_2	F	Significance
Test Score							
Forward	26	62.4	17.9	1	43	0.64	N.S.
Pretest Forward	20	63.8	21.4				
Learning Time							
Forward	27	110.2	23.3	1	44	8.6	@ .004
Pretest Forward	20	91.9	17.9				
Test Time							
Forward	27	27.3	5.7	1	44	9.0	@ .005
Pretest Forward	20	21.7	6.5				

TABLE XI

FORWARD-BRANCHING PROGRAM IN BOX vs. IN TEST

	N	Adj. Mean	S.D.	V_1	V_2	F	Significance
Test Score							
Box	26	62.4	17.9	1	49	2.87	N.S.
Text	26	53.2	22.5				
Learning Time							
Box	27	110.2	23.3	1	50	27.3	@ >.0005
Text	26	80.2	19.3				
Test Time							
Box	27	27.3	5.7	1	50	0.68	N.S.
Text	26	30.2	16.9				

TABLE XII

PERCENTAGE OF STUDENTS BRANCHING AT EACH PROGRAM CONCEPT

	Concept 1	2	3	4	5	6	7
Backward	28	34	17	41	10	21	17
Backward Alternate	32	28	16	40	24	24	20
Forward	47	11	70	20	23	11	17
Pretest Forward	80	30	90	15	35	10	35

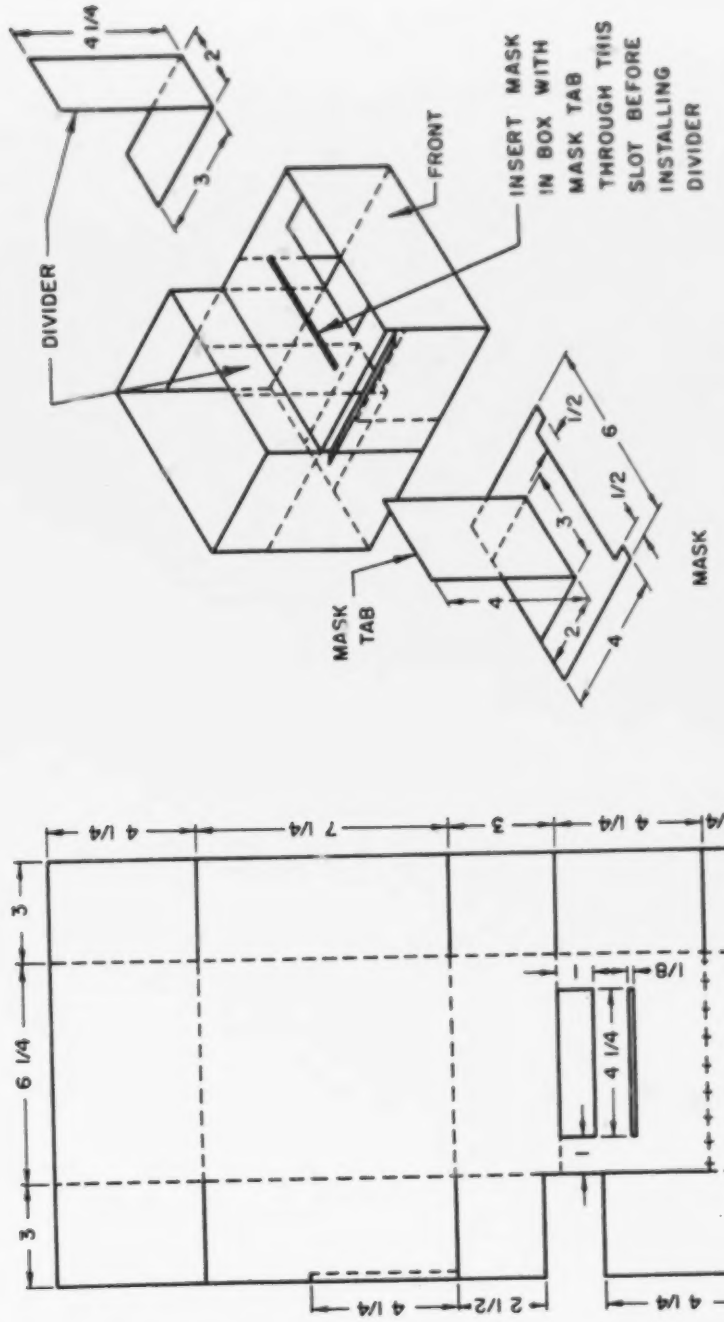
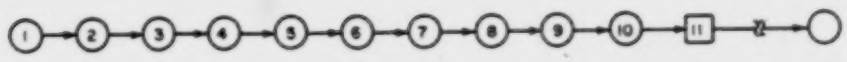

4 1/4
2
3
DIVIDER
FRONT
INSERT MASK IN BOX WITH MASK TAB THROUGH THIS SLOT BEFORE INSTALLING DIVIDER
MASK TAB
4
2
3
1/2
6
1/2
4
MASK
4 1/4
7 1/4
3
4 1/4
1/4
3
6 1/4
3
1
1/8
4 1/4
2 1/2
4 1/4
CUT
FOLD FORWARD
FOLD BACKWARD

FIGURE 1

AUTOMATED TEACHING METHODS USING BRANCHING PROGRAMS

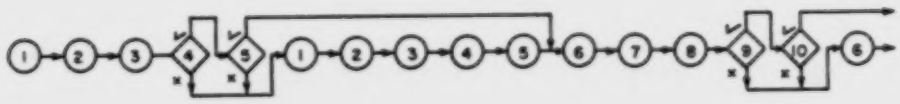
FIGURE 2

LINEAR (NO BRANCHING)



FORWARD BRANCHING

BACKWARD BRANCHING



Decision Items

Non-Decision Items

Review Items

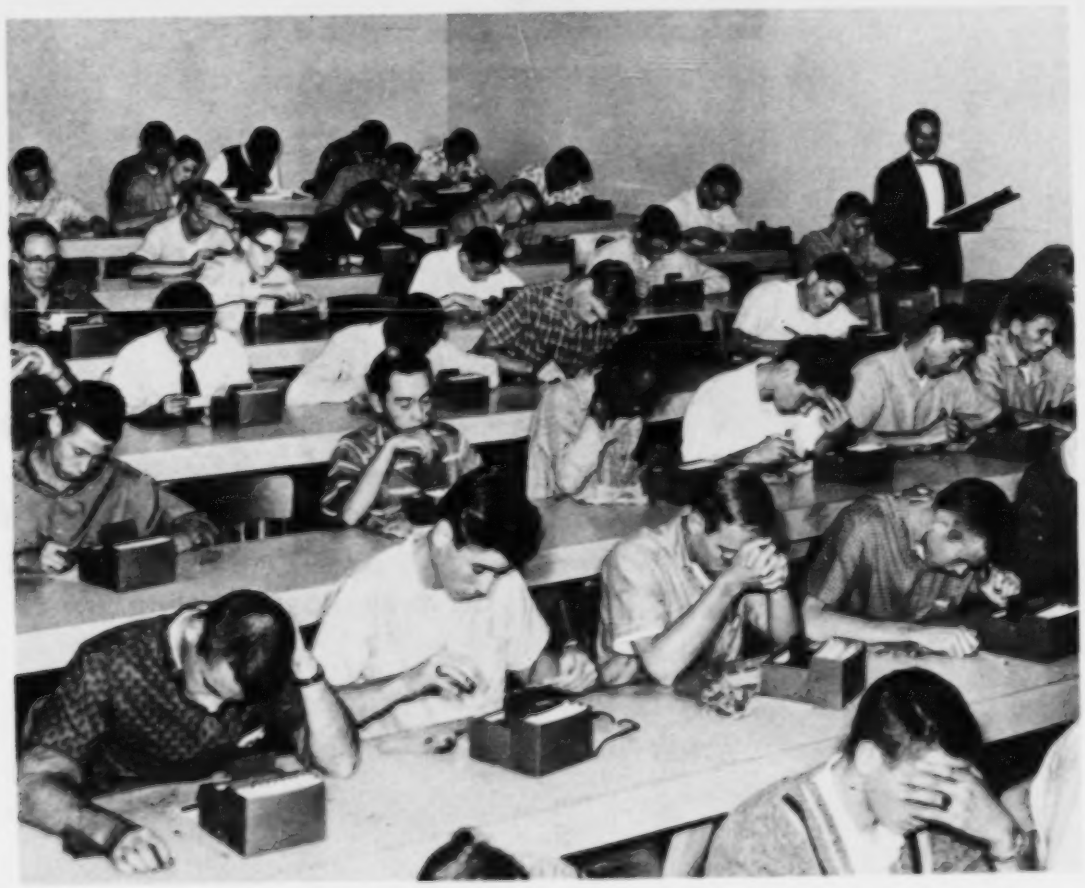
Correct Response to Decision Item

Incorrect Response to Decision Item

BRANCHING FORMATS

FIGURE 3

FIGURE 4



Freshman students in the Department of Engineering, UCLA, studying a program on elementary probability from a branching box.